1970-06

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by

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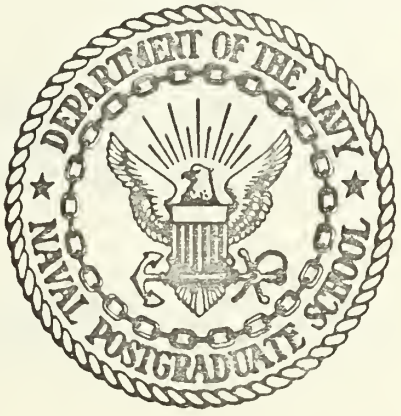

THESIS

A MONITOR FOR

THE PDP-8/S COMPUTER SYSTEM

by

Glenn Tracy Martinsen

June 1970

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN COMPUTER SCIENCE

from the

NAVAL POSTGRADUATE SCHOOL
June 1970

ABSTRACT

The design and implementation of the PDP-8/S Monitor is described. The monitor is an interactive tape driving routine combined with a small operating system. The monitor was implemented in PAL III, the PDP-8 assembly language, for operation in conjunction with a teletype and PI-1250-1 Data Handling System.

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I. INTRODUCTION

The PDP-8/S[1] computer is input/output bound when the only peripheral device is a teletype and paper punch/reader unit. The addition of a tape drive, tape controller, and monitor software improves the overall capability of the system.

This thesis describes the development and implementation of an interactive tape driver system and small operating system. In order to produce a basic monitor system in a reasonably short length of time existing PDP-8 software was utilized where practical and manufacturer's design recommendations were followed when feasible. The steps taken to implement a monitor were: (1) gather and study available literature concerning the PDP family of computers; (2) decide on internal core paging requirements; (3) write elementary programs for the monitor; (4) write input and output routines for the teletype; and (5) write input and output routines for the tape system.

A basic knowledge of PDP-8 assembly language [Refs. 1 and 2] is essential to a clear understanding of this thesis. The conventions, abbreviations, and descriptive terms contained herein are those found in [Refs. 1-5].

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[1]The PDP-8/S is one of a family of small computers called PROGRAMMED DATA PROCESSORS manufactured by DIGITAL EQUIPMENT CORPORATION, Maynard, Mass.

II. DISCUSSION OF COMPUTER AND TAPE SYSTEMS

The computer system was configured with a PDP-8/S computer, a teletype with integral paper tape reader and punch, and a PI-1250-1 data handling system. This section will discuss each component of the entire system in relation to the requirements placed upon the monitor design.

A. PDP-8/S COMPUTER AND TELETYPE UNIT

The PDP-8/S is a general purpose digital computer operating on 12 bit binary words and having a four micro-second core cycle time. It is a single-address parallel machine using two's complement arithmetic. It is composed of four basic components: (1) Input/Output units; (2) Arithmetic unit; (3) Control unit; and (4) Memory unit.

1. Input and Output Units

Input and output devices are combined since many devices serve both functions. The primary input/output device is the teletype with integral paper tape reader/punch. All input or output associated with the teletype unit must be under program control and pass through the accumulator to be discussed later in this section. No direct transfer of information to or from memory is permitted. Because there is a great difference in the processing speed of the computer and the speed of most peripheral devices, the computer must be programmed to check the readiness of a device before any

transfer of information is performed. The PDP-8/S console allows the operator direct access to core memory and the program counter by setting a series of switches, enabling manual storage of programs and examination of information previously stored.

2. Arithmetic Unit

The arithmetic unit accepts data from input devices and transmits processed data to the output devices as well. Primarily, the unit performs calculations under the direction of the control unit. This arithmetic unit consists of a twelve bit register, called an accumulator, and a link bit. Bits are numbered from 0 to 11 starting at the left side of the accumulator and moving right.

The accumulator performs binary operations under the supervision of the control unit. Whenever the binary addition causes a carry out of the most significant bit, the carry is lost from the accumulator and causes the link bit to be set. The link bit is actually a one bit register logically attached to the accumulator. If a carry results from an addition in the accumulator, the link bit is complemented. This carry results in a link value change from 0 to 1, or 1 to 0, depending upon the original state of the link.

Positive numbers can be represented from 0 up to 3777_8 and negative numbers from -3777_8 up to -1. By convention, bit 0 specifies the sign bit (0 for positive and 1 for negative). In

decimal form then numbers from -2048 up to and including +2047 can be represented internally in a single twelve bit word.

3. Control Unit

The control unit is composed of three parts: (1) the instruction register; (2) the major state generator; and (3) the program counter. Together these registers follow what the computer is doing now and what it will do next, thus specifying the flow of the program from beginning to end.

The program counter is used to record the location in memory of the instructions to be executed. The counter always contains the address of the next instruction to be executed and normally, except in the case of branches, merely increments itself by one.

The instruction register is used by the control unit to specify the main characteristics of the instruction being executed. The first three bits (0-2) specify the operation to be performed and the remaining nine bits (3-11) specify the operand.

The major state generator establishes the proper states in sequence for the instruction being executed. One or more of the following three major states are entered serially to execute such programmed instruction. During a fetch state, an instruction is loaded from core memory, at the address specified by the program counter, into the memory buffer register. The defer state is used in conjunction with indirect addressing to obtain the effective

address. The execute state performs the operation specified in the memory buffer register.

4. Memory Unit

The memory unit consists of 4,096 12 bit words of magnetic core memory, a 12 bit memory address register, and a 12 bit memory buffer register. Core memory is a form of random access storage, meaning any specific location can be reached in memory as readily as any other. Each word in memory requires a 12 bit address to specify the location uniquely.

The memory buffer register provides temporary storage prior to being used in the accumulator. Thus, the memory buffer holds all words that go into and out of memory, updates the program counter, sets the memory address register, and accepts information from or provides information to the accumulator.

The memory address register holds the address specified by a memory reference instruction. It is also used to specify the address of the next instruction to be brought out of memory and executed. The register can be used to directly address all of memory. It can be set by the memory buffer register, or by input through the program counter register, or by the program counter itself.

Since twelve bits are needed to address each word in core and only nine bits are available to specify an operand, core memory is divided into 40_8 pages of 200_8 words each. This arrangements allows bits 5 through 11 to be used to specify the desired address on the

current page. Bit 4 is used to specify an address on the current page by a 1 or on page zero by a 0. Bit 3 specifies whether direct addressing (set 0) or indirect addressing (set 1) is to be used. Table I demonstrates the paging scheme utilized in the PDP-8.

B. PI-1250-1 DATA HANDLING SYSTEM

The PI-1250-1 Data Handling System is a seven track magnetic tape system designed to operate with the PDP-8 family of computers. The system is composed of a PI-1207 RW Digital Tape Recorder and an interface device designated as an Information Controller unit, which contains the logic allowing data to be transferred to or from the computer under program control.

1. Data Representation and Transfer

Information records are written on tape in seven-bit characters composed of six data bits and an odd parity bit developed by the PI-1207 RW unit. All data is transferred from the computer to the tape except for parity, exactly in the character sequence as it appears in the accumulator; conversely, data is transferred to the computer exactly as it appears on tape.

All inter-record gaps must be recorded under program control; however, they are detected automatically causing certain bits in the status register to be set which can be examined under program control.

When reading data, two characters are read from the tape, assembled as a twelve bit word, and a data transfer request is

TABLE I

PAGING SCHEME FOR PDP-8

Page	Memory Location
0	0-177
1	200-377
2	400-577
3	600-777
4	1000-1177
5	1200-1377
6	1400-1577
7	1600-1777
10	2000-2177
11	2200-2377
12	2400-2577
13	2600-2777
14	3000-3177
15	3200-3377
16	3400-3577
17	3600-3777
20	4000-4177
21	4200-4377
22	4400-4577
23	4600-4777
24	5000-5177
25	5200-5377
26	5400-5577
27	5600-5777
30	6000-6177
31	6200-6377
32	6400-6577
33	6600-6777
34	7000-7177
35	7200-7377
36	7400-7577
37	7600-7777

initiated to place the word in the accumulator. When recording data, a twelve bit word is accepted, disassembled, and written as two six bit characters. Data can be transferred at incremental and slew speed to be compatible with the PDP-8/S. A high speed is used only with the controller's registers for searches and under monitor control.

Errors are handled through the logical structure of the controller. This includes the detection and reporting to the computer utilizing a program interrupt. These errors are: (1) write or read operation unreadiness; (2) transfer rate errors; and (3) transfer data error (parity).

2. Information Controller

The information controller includes within its structure the means to receive, interpret, and retain commands; carry out a control operation; and notify or respond to the occurrences of a key event. The logical structure of the information controller is comprised of nine units.

a. Instruction Decoder

The instruction decoder provides the controller with the logical ability to receive a standard set of codes generated by the computer and decodes these signals into separate and mutually exclusive occurring commands to perform either a data transfer or to initiate, or suspend, an operation. The mnemonic code, octal code, and operation of all instructions is listed in Table II.

TABLE II

INSTRUCTION SET FOR INFORMATION CONTROLLER

MNEMONIC CODE	OCTAL CODE	OPERATION
PSSR	6701	Skip if system ready
PWMS	6702	Write mode select
PBOT	6704	Write beginning of tape
PSSF	6711	Skip on system flag
PREV	6712	Reverse read select
PFRD	6714	Forward read select
PSRF	6721	Skip on data rate error flag
PEOF	6722	Write End of file
PRDL	6724	Ready/Load
PSPF	6731	Skip on Vertical Parity error
PCLR	6732	System clear
PHLT	6734	Halt
PCHLT	6736	System clear/halt
PSDF	6741	Skip on data flag
PLMF	6742	Load memory Field Extension register and interrupt
PLDS	6744	Load data buffer register and step (write mode)
PRDS	6751	Read data buffer Register (Read mode)
PSER	6752	Skip if end of record flag
PSMS	6754	Slew mode select
PSSS	6761	Sense system status
PINS	6762	Incremental mode select
PREW	6764	Rewind select
PEOR	6771	Write end of record and halt
PHAS	6772	High speed accumulator I/O select
PERHS	6773	Write End of record/High Speed Accumulator I/O

b. Data Buffer Register

The data buffer register is a twelve bit register which serves as a buffer for data traffic between the tape and accumulator. This register is automatically cleared after a word is transferred to the tape unit or to the computer.

c. Read/Write Mode and Speed Select Register

This register receives direct commands from the instruction decoder to either start, maintain or suspend an operation related to one of three speeds and to either reading or recording.

d. Data Flag Register and Logic

This register is comprised of two bits, the read bit and write bit which, when set during programmed data transfer operations, communicate that the information coupler is ready for a data transfer with the computer.

e. System Status Register

The system status register is comprised of ten memory elements referred to as locks and identified as Vertical Parity Error, Data Rate Error, End of Record, End of Tape, Longitudinal Parity Error, Load Point, Beginning of Tape, Write Lockout Ring, End of File, and WCO Read.

Each of these possible conditions may be tested when the contents of the status register are transferred to the computer's accumulator. In addition console lights will be illuminated when any or all conditions exist. This enables a general program mask to be used and gives the operator the capability of reading the error from the console.

f. Reverse/Forward, Rewind and Ready/Load Register

This register controls the direction of the tape drive. Reverse and forward are complementary events and are implemented with a single bit. In addition the rewind lock is set by the occurrence of the rewind command and remains set until cleared by the halt or clear command or by the sensing of the beginning of tape reflective marker traveling past the photodetector. The ready/load logic task is to communicate to the read-write unit the proper commands at the beginning of an operation after initial tape mounting and threading.

g. Other Units

Three other components exist for high speed operation only and are not required for monitor operation. The PDP-8 does not have the capability to transfer or receive data at the rate described by this operational speed.

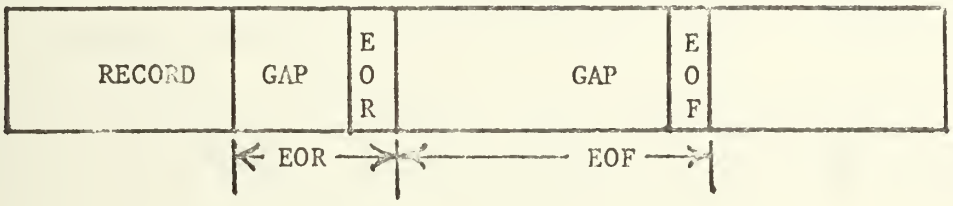
3. Gap Detection Logic

Gap detection logic included in the information controller continuously monitors the retreived information to determine and indicate when a data record readout has concluded and, as a consequence, activates auxiliary logic to read the logical record control character (LRCC), end of record (EOR), and end of file (EOF) characters without causing any operational ambiguities.

After the absence of two characters is determined, logic is activated to interrogate the validity of the LRCC character, and if an error is indicated the LRCC lock is set to communicate such an error through the status register to the computer.

To detect the end of file character, the gap logic retains in memory the fact that a single character record was read out, absence of two characters was determined, and if another character appears within the next two characters cell times, then it must be the LRCC character corresponding to the single EOF character.

The correct sequence for an EOR followed by an EOF is shown below.



III. DESIGN AND IMPLEMENTATION OF MONITOR

In any system that has more than one input/output device, the computer is required to handle many tasks almost at the same time in order to make the system function as a unit. A set of programs assigned the task of control and communications within the system is called the monitor.

The monitor is designed in such a manner so as to simplify the programming effort required by the user. It is not necessary for the user to have detailed knowledge of the entire system; but, instead, the user should have a general overall view of the computer and its monitor options. The monitor provides all the input and output operations and controls the message traffic between peripheral devices and the computer. System errors are detected by the

monitor and reported to the user eliminating the need for constant system checking by the user programs.

Many programs contained within the monitor may be called upon to serve user programs. These are normally input and output procedures and are all written as subroutines in this monitor to allow easy user access. Support programs are needed to install the monitor and keep it running smoothly. Normally the user will not need to call upon these routines. A third set of programs is necessary to assist the monitor in its assigned tasks. These procedures are written as subprograms within this monitor structure and are used to handle the pseudo commands available to the user.

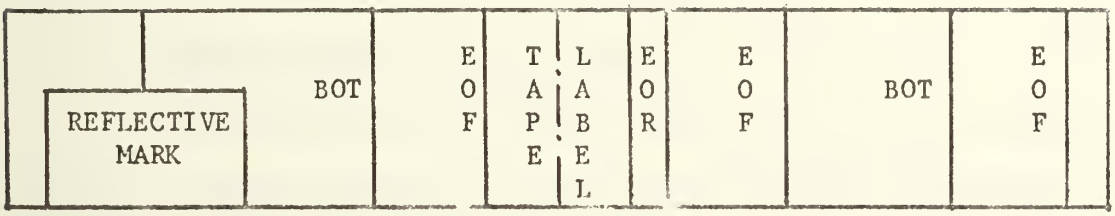
Most programs written for the PDP-8 computer are loaded into core memory from paper tape punched in binary code. Many system programs, such as the editor and assembler routines, require as much as twelve minutes to read into memory. Through the use of a magnetic tape system, these same programs can be loaded into the computer in ten to fifteen seconds. This section describes the magnetic tape organization, the core memory requirements of the monitor, and the program specifications and conventions of the monitor.

A. MAGNETIC TAPE ORGANIZATION

The magnetic tape is divided into four sections providing a logical arrangement for the files stored. These sections are: (1) Tape label; (2) Monitor; (3) System and user program library and (4) Scratch pad work area.

1. Tape Label

The tape label is required by the monitor to maintain a count of end of file marks appearing on the tape. The label is a one word (two character) file preceded by a beginning of tape gap (BOT) and end of file mark; and followed by EOR, EOF, BOT, and EOF. The label and appropriate gaps are depicted below.



The label is written in binary form as an octal number and can easily be located since it is the first record to appear on the magnetic tape. The BOT mark is a length of erased tape placed so as to give the read head a reference point from which to start. The second BOT is provided as protection for the programs recorded.

By reading the number written in the tape label an accurate count of the number of EOF marks appearing on the tape can be read into the computer. This number can then be used by the monitor to find the desired position to write a new record, to locate the scratch pad area, or to check for errors.

2. Monitor Storage

The monitor appears as the first complete program recorded on the tape. It is located immediately after the tape label with associated gaps. Since the monitor is the most frequently used program, it should appear close to the beginning of the tape for more rapid loading, minimizing the search time required.

It is unnecessary to read the tape label in order to load or store the monitor since three EOF marks always precede the monitor in its storage location. Any time the monitor is required, the tape label counter is generated by the program rather than by reading the label. Immediately following the monitor on tape an EOR and EOF are written to separate it from following files.

3. System and User Program Library

PDP-8 system programs appear immediately after the monitor on tape. Programs designed by users and to be added to the tape system are appended after system programs.

System programs are arranged in a logical sequence dictated by their normal usage in most programming efforts. Master tapes can be prepared with these programs placed in any order, but a suggested master tape system program sequence follows.

MONITOR
SYMBOLIC EDITOR
PAL III ASSEMBLER
ODT LOW
HELP BOOTSTRAP
USER PROGRAMS

This list places the most needed programs early on tape and then in order of their usage. For example, the Editor and Assembler are required equally but the Editor is normally used prior to the Assembler; thus, the ordering is as listed.

User programs follow no usage scheme as do system programs. Instead, user programs appear on tape in the order that they were

recorded without regard as to their potential usage. A new master tape can be generated at any time to order user programs as desired.

4. Scratch Pad Area

The user may at any time desire to utilize a scratch pad area of tape without engaging monitor or system programs. Immediately following the last program recorded approximately ten feet of blank tape is supplied as separator for system protection and an EOF is recorded marking the beginning of the scratch pad section. Return to this area can be accomplished programmatically by the user to recover data stored in that area.

Since no other safeguards exist for the system tape, the user must insure that no scratch pad recording is done prior to the designated portion of tape. Suggested methods for using the scratch pad section appear in Appendix A.

B. MEMORY REQUIREMENTS

The core memory of the PDP-8/S is restricted to 4,096 words and, as such, an executive routine must be extremely compact and limited in its scope. The monitor occupies pages 30_8 through 37_8 inclusive, or address 6000_8 through 7777_8. In addition locations 0100_8 to 0141_8 are required only when loading the monitor, either under monitor control or by the bootstrap program.

The monitor is divided into two separate sections. Section I consists of pages 30_8 through 32_8 and Section II, the mini-monitor, of pages 33_8 through 37_8.

1. Monitor-Section I

Section I of the monitor may be destroyed by the user without adverse effect upon the primary functions of the monitor. Loss of four commands from the code list will be experienced; however, all store, load, input and output routines will be retained in the mini-monitor. In addition the ability to regain the entire monitor rests solely with Section II. This feature enables the user more core memory space without undue loss of performance from the monitor system. The user commands as much of memory as is practical; page 0 except for locations 0100_8 to 0141_8, thus retaining autoindexing registers at locations 0100_8 through 0017_8 as discussed in Ref. 1, the remaining pages up to 30_8, and if desired up to page 33_8. This memory area should be more than adequate for most programming efforts.

2. Monitor-Section II (Mini-Monitor)

Section II of the monitor contains the primary service routines normally required by users. Page 37_8 of the mini-monitor contains one PDP-8 system programs, the BIN loader. This program allows a user to load a binary paper tape into memory at the required locations.

If the user desires he may utilize all of core up to page 37_8 for his programming, resulting in destruction of the monitor. To reload the monitor in its entirety the recover procedure is utilized to read the entire monitor program into memory from magnetic tape. This is accomplished by setting 7600_8 into the switch register,

depressing load address, and start. Rewind must be executed manually by using the PI 1207 RW control panel.

C. PROGRAM SPECIFICATIONS AND CONVENTIONS

Twenty-nine separate programs and subroutines comprise the monitor. Fourteen subroutines are concerned only with input and output and are discussed in great detail in Appendix A. Eight subprograms are used to respond to requests given by the user and the remaining programs are utility routines integral to the monitor.

Each of the eight pages of the monitor will be discussed generally in this section and explained in more detail in the User's Manual, Appendix A.

1. Page 3_8 - Monitor Code

This page contains the program for listing the commands acceptable to the monitor, and monitor responses to those commands. The list below is a sample that is printed on the teletype in response to the command "C" given to the monitor.

```
S = STORE PROG.
L = LOAD # PROG.
M = LOAD MONITOR
T = LIST TAPE
C = MONITOR CODE
P = SCRATCHPAD
R = ERASE AFTER #
X = EXECUTED
E = TAPE ERROR
N = STORE MONITOR
? = NEXT COMMAND
```

2. Page 31_8 - List

This page contains the coding necessary to list the system library and associated numbers that are recorded on magnetic tape.

This list is easily appended or changed in order to add to the list (maximum of 15 may be listed) or make different lists for various tapes. Below is a sample output from the monitor's response to the request "T".

```
 M = MONITOR
02 = EDITOR
03 = PAL III
04 = ODT LOW
05 = HELP BOOTSP.
```

3. Page 32_8 - Erase and Store Monitor

This page is the last of Section I that is not required for primary operation of the monitor. The Erase procedure changes the tape label to reflect that any number of files have been deleted as long as they are located concurrently at the end of the list of files.

The Store Monitor routine is utilized to record the monitor when a new master tape is being formed. The initial tape label is written during the recording of the monitor, thus initializing the tape.

4. Page 33_8 - Store, Clear and Teletype

This page contains the programs necessary to record a user program at the end of the tape file. User programs may be loaded anywhere in memory between 0_8 and 6577_8 to be recorded on tape. The monitor responds with the numbered position of the recorded program. To retrieve this same program the number must be retained. An "X" is then typed to indicate that the operation has been executed.

The clear procedure is used by the monitor to clear all system flags located in the data handling system and teletype.

The necessary routines for operation of the teletype by the user or the monitor are located on this page. They include: (1) Carriage return and line feed subroutines; (2) Type subroutine; and (3) List subroutine. These allow the system to type characters one at a time or receive characters one at a time through the accumulator.

5. Page 34_8 - Monitor Utility

Utility routines are located on this page. These programs form the tape label in correct format and decide which branch is to be taken upon receiving a command from the teletype.

6. Page 35_8 - Tape Subroutines and Scratch Pad

All subroutines for operating the tape drive must be on the same page. Many of the subroutines reference others listed on this page, thus reducing the amount of indirect calls. These routines enable the user or monitor to record, read, rewind, write logical gaps, or search the tape for appropriate records. Table III, Appendix A, lists each subroutine, address, and use.

A PAD subprogram is used to locate the scratch pad area on tape. In response to the command "P" the monitor transfers control to this procedure and the scratch pad area is located. The program then is terminated allowing the user complete control of the tape system.

7. Page 36_8 - Load and Load Monitor

Any numbered record on tape may be loaded into the computer memory through the use of the "L" command. Transfer of control is

assumed by the Load program and the symbols "#?" are typed. The desired number is entered on the keyboard and a check against the tape label is performed to insure a proper request has been made; if not, an "E" is typed indicating an error. If the request is valid the designated program is loaded into memory between addresses 0_8 and 6577_8.

The Monitor may be recalled in its entirety at any time by the command "M". Code is transferred to locations 0100_8 to 0141_8 and control is shifted to this bootstrap. The monitor is reloaded and control shifts to the Utility package on page 3_8.

8. Page 37_8 - Recover and Binary Loader

If only the top page of the monitor remains the recover procedure will enable the user to regain the full monitor program.

The Binary loader is a PDP-8 package enabling the user to load desired programs at the proper address in memory. This package is fully described in Ref. 1 and 5.

D. PAL III ASSEMBLER MODIFICATION

The mnemonic codes for tape control are not included in the assembler's permanent symbol table. Table II lists the mnemonic codes for the data handling system and were added to the permanent symbol table as explained in Ref. 2.

IV. RECOMMENDATIONS

In any system design project additional features seem to be desired. Not all design requirements were incorporated into the monitor but are presented here as a possible addition to the present system.

A. REVISED TAPE LABEL FORMAT

The existing tape label format allows for only one number to be written. A new tape label containing more information is desirable. The tape reel number, date of tape production, and number of records present should be recorded in addition to the counter. When the tape is loaded and monitor activated initially, the label should be read and typed on the teletype informing the user that the tape is the correct one selected and that the monitor is ready for use.

B. SCRATCH PAD RETURN COMMAND

The current design of the monitor allows the user a designated area to be utilized as desired. Return to this area can be accomplished by programmed control and must be specified by the user as explained in The User Manual, Appendix A.

A more convenient method would be to add one more command to the monitor, performing the same task that the user must.

With each addition to the monitor it must be remembered that more memory is required and as a consequence user space is restricted. The design of such a monitor is a compromise at best and not all recommended changes may be feasible to incorporate.

APPENDIX A

PDP-8/S MONITOR USER'S MANUAL

This appendix lists step-by-step procedures for complete operation of the monitor system. Any special features or error messages are explained at the end of each section. Table III is presented as an aid in locating helpful input/output subroutines.

1. Initial Loading of Monitor

1. Power on all units
2. Load tape reel
3. Press Load and Ready switches on PI 1207 RW (tape is positioned to reflective marker)
4. Set 0100 in switch register; depress load address
5. Toggle in the bootstrap octal code listed in Appendix B
6. Set 0100 in switch register; depress load address
7. Depress start.

This activates the program and in turn the tape is positioned to read the monitor into the computer memory. After the tape has halted, depress the rewind selected on the PI 1207 RW.

2. Monitor Execution

1. Is monitor loaded? If not execute section 1
2. Set 7000 in switch register, depress load address
3. Depress start
4. A question mark is typed; if not check section 2, then re-execute section 1 and 2.

Once the monitor has been executed the order in which the pseudo commands are given depends entirely upon the user's desires. It is suggested that the "T" and "C" be executed to insure that the correct numbers for system programs and the correct code for monitor operation is obtained. Future sections will be presented in a

logical manner as though a program were to be developed from beginning to end.

3. Pseudo Command "L" (Load a Program)

1. Type "L" on keyboard in response to monitor's "?"
2. Teletype responds with "#?"
3. Type 2 digit number corresponding to desired program (i.e., 02 to load the editor program)
4. Program is loaded or "E" is typed indicating number entered is larger than tape label file and program requested is nonexistent
5. An "X" is typed indicating operation is complete, tape is rewound and stopped
6. Depress stop
7. Set initial address of requested program in switch register, depress load address
8. Depress start.

If a system program is loaded the system manual should be consulted for correct operation. If a user program is loaded, the starting address will remain the same as programmed. Execution of any program is discussed in Ref. 1. It is not necessary to store any system program after use since a fresh copy is always available on tape. Other programs may be loaded over the current one. If an "E" is typed after the loading of the program, inspection of the tape controller register will indicate the type of error generated on the tape system. In this case retry by repeating section 3.

4. Pseudo Command "S" (Store a Program)

1. Load program from binary tape utilizing BIN loader as specified in Refs. 1 and 5.
2. Restart monitor in accordance with section 2.
3. Type "S" in response to "?"
4. Program is recorded and "X" is typed
5. "#xx" is typed indicating number assigned to recorded program. Symbols xx are filled with the two digit octal number
6. Rewind is initiated and tape halted.

The number returned is the only identification a program receives and must be retained. When it is desired to load the same program the number is typed in response to the "#?" generated by the load procedure. It is recommended that the ODT LOW (debugging) procedure be loaded prior to loading the binary tape of the user program. This will enable the user more flexibility in changing his routines without the necessity of repeating the programming effort.

5. Pseudo Command "M" (Load the Monitor)

1. Monitor in control in accordance with section 2
2. Type "M" in response to "?"
3. Monitor is loaded and executed.

An error will be indicated if a "?" is not typed and inspection of the tape controller register will indicate the error. In this case a manual rewind must be executed on the PI 1207 RW unit and address 0100 loaded and executed manually on the console.

If user programs destroyed all of the monitor except the top page of memory, the recover procedure may be initiated by setting 7600_8 into the switch register, depressing load address, and start. A manual rewind must be performed after the tape has halted. Execute the monitor as described by section 2. If all of the monitor was destroyed section 1 and 2 must be executed to restart the entire system.

6. Pseudo Command "R" (Erase Program from Tape)

1. Type "R" in response to "?"
2. Monitor responds with "#?"
3. Type the number of the first program that is desired to be removed from the tape file
4. Tape label is checked to insure it is greater than number entered. If not "E" is typed indicating improper input from keyboard
5. Tape label is rewritten reflecting new tape file and rewound
6. An "X" is typed indicating that the operation executed

Tapes are not random access devices and, as such, cannot have files deleted randomly. Only files at the end of the tape may be deleted. The number entered is the first record to be deleted, but all records following that will be deleted as well.

7. Pseudo Command "N" (Store Monitor)

1. Load monitor from paper tape as described in BIN procedure
2. Execute monitor as described in section 2
3. Type "N" in response to "?"
4. Monitor and initial tape label are recorded. Rewind procedure is executed.

The store monitor procedure should only be executed when forming a new master tape. A special procedure is required to initialize the tape label and record the monitor since the memory location and size is different than user or system programs.

8. Pseudo Command "P" (Scratch Pad)

1. Type "P" in response to "?"
2. Tape positioned to scratch pad area
3. Tape halts.

The user may now halt the monitor and begin using the tape as additional storage; however, the tape must be programmed in assembly

language or by subroutine jumps to the tape program listed in Table III. Examples of their usage are depicted in Appendix B.

9. Teletype Input/Output

Many schemes can be utilized to print or retrieve information using the teletype. Packed coding is described in Ref. 1, indicating the proper procedures needed to pack and unpack ASCII code. All schemes need the ability to read and write the characters desired. Three procedures are necessary for teletype operation. Their locations are listed in Table III and may be used by subroutine calls to receive into the accumulator information entered from the keyboard, type information placed in the accumulator, and a carriage return line feed routine for control.

TABLE III

INPUT/OUTPUT SUBROUTINES

SUBROUTINE TITLE	OCTAL ADDRESS	OPERATION
CRLF	6665	Carriage return and line feed
TYPE	6676	Print one character
LISN	6704	Receive one character
READY	7200	Delay until tape is ready
WRITE	7204	Set up for write operation
READ	7211	Set up for read operation
WRBOT	7217	Write beginning of tape
WREOR	7230	Write end of record
WREOF	7240	Write end of file
REWIND	7250	Rewind tape and halt at load point
FLABEL	7263	Find tape label
RDTLB	7277	Read tape label
WRTLB	7312	Write tape label
SEARCH	7324	Search tape for desired record

APPENDIX B
PDP-8/S MONITOR LISTING

BOOTSTRAP

```
ADDRESS  CODE                MNEMONIC CODE     COMMENTS
                             *0100
0100     7300    BOOT,       CLA CLL
0101     6714                 PFRD
0102     6701                 PSSR
0103     5102                 JMP.-1
0104     6732    S,          PCLR
0105     6754                 PSMS
0106     7300                 CLA CLL
0107     6761                 PSSS
0110     0125                 AND EOF
0111     7650                 SNA CLA
0112     5107                 JMP.-3
0113     2126                 ISZ C
0114     5104                 JMP S
0115     7300                 CLA CLL
0116     6751                 PRDS
0117     6741                 PSDF
0120     5117                 JMP.-1
0121     3527                 DCA I AD
0122     2127                 ISZ AD
0123     5115                 JMP.-6
0124     7402                 HLT
0125     0010    EOF,         0010
0126     7775    C,           7775
0127     6000    AD,          6000
```

MAIN MONITOR LISTING

```
                             *6000
6000     7300    CODE,       CLA CLL /CLEAR AC & LINK
6001     6046                 TLS     /CLEAR PRINT FLAG
6002     1253                 TAD F   /LOAD BASE
6003     3252                 DCA D   /STORE BASE
6004     1247                 TAD CC  /LOAD COUNTER
6005     3250                 DCA C
6006     4644    J2,          JMS I CRLF      /CARRIAGE RETURN
6007     1245                 TAD A   /LOAD -8
6010     3246                 DCA B   /LOAD COUNTER
6011     1652    J1,          TAD I D /LOAD 2 CHARACTERS
6012     4221                 JMS TCP /PRINT 2 CHARACTERS
6013     2252                 ISZ D   /D=D+1
6014     2246                 ISZ B   /SKIP WHEN LINE PRINTED
6015     5211                 JMP J1  /RETURN
6016     2250                 ISZ C   /SKIP WHEN ALL LISTED
6017     5206                 JMP J2  /RETURN
6020     5651                 JMP I MON       /RETURN TO MONITOR
```

```
6021  0000  TCP,    0          /SUBROUTINE TO PRINT 2 CHAR.
6022  3237         DCA B1     /STORE 2 CHARACTERS
6023  1237         TAD B1     /LOAD SAME CHARACTERS
6024  0241         AND C1     /MASK LAST 6 BITS
6025  7112         CLL RTR    /ROTATE 2 RIGHT
6026  7112         CLL RTR    / "
6027  7112         CLL RTR    / "
6030  1240         TAD C2     /GENERATE ASII
6031  4643         JMS I TYPE       /TYPE SUBROUTINE
6032  1237         TAD B1     /LOAD CHARACTERS
6033  0242         AND C3     /MASK FIRST 6 BITS
6034  1240         TAD C2     /GENERATE ASII
6035  4643         JMS I TYPE       /TYPE SUBROUTINE
6036  5621         JMP I TCP        /RETURN
6037  0000  B1,     0          /BUFFER
6040  0240  C2,     240        /ASII FOR SPACE
6041  7700  C1,     7700       /MASK FOR LAST 6 BITS
6042  0077  C3,     77         /MASK FOR FIRST 6 BITS
6043  6676  TYPE,   6676
6044  6665  CRLF,   6665
6045  7770  A,      7770       /-8
6046  0000  B,      0          /BUFFER
6047  7765  CC,     7765       /-11
6050  0000  C,      0          /BUFFER
6051  7000  MON,    7000       /MONITOR ADDRESS
6052  0000  D,      0
6053  6054  F,      .+1        /ADDRESS OF E
6054  6300  E,      6300       /LIST OF CODE TO FOLLOW
6055  3500         3500
6056  6364         6364
6057  5762         5762
6060  4500         4500
6061  6062         6062
6062  5747         5747
6063  1600         1600
6064  5400         5400
6065  3500         3500
6066  5457         5457
6067  4144         4144
6070  0003         0003
6071  0060         0060
6072  6257         6257
6073  4716         4716
6074  5500         5500
6075  3500         3500
6076  5457         5457
6077  4144         4144
610   0055         0055
610.  5756         5756
6102  5164         5164
6103  5762         5762
6104  6400         6400
6105  3500         3500
```

6106	5451	5451
6107	6364	6364
6110	0064	0064
6111	4160	4160
6112	4500	4500
6113	0000	0000
6114	4300	4300
6115	3500	3500
6116	5557	5557
6117	5651	5651
6120	6457	6457
6121	6200	6200
6122	4357	4357
6123	4445	4445
6124	6000	6000
6125	3500	3500
6126	6343	6343
6127	6241	6241
6130	6443	6443
6131	5000	5000
6132	6041	6041
6133	4400	4400
6134	6200	6200
6135	3500	3500
6136	4562	4562
6137	4163	4163
6140	4500	4500
6141	4146	4146
6142	6445	6445
6143	6203	6203
6144	7000	7000
6145	3500	3500
6146	4570	4570
6147	4543	4543
6150	6564	6564
6151	4544	4544
6152	0000	0000
6153	0000	0000
6154	4500	4500
6155	3500	3500
6156	6441	6441
6157	6045	6045
6160	0045	0045
6161	6262	6262
6162	5762	5762
6163	0000	0000
6164	5600	5600
6165	3500	3500
6166	6364	6364
6167	5762	5762
6170	4500	4500
6171	5557	5557
6172	5616	5616

```
6173  0000            0000
6174  3700            3700
6175  3500            3500
6176  5645            5645
6177  7064            7064
6200  0043            0043
6201  5755            5755
6202  5541            5541
6203  5644            5644

                      *6204
6204  7300  LIST,     CLA CLL /CLEAR AC & LINK
6205  6046            TLS     /CLEAR PRINT FLAG
6206  1257            TAD F   /LOAD BASE
6207  3256            DCA D   /STORE BASE
6210  1253            TAD CC  /LOAD COUNTER
6211  3254            DCA C
6212  4650  J2,       JMS I CRLF      /CARRIAGE RETURN
6213  1251            TAD A   /LOAD -8
6214  3252            DCA B   /LOAD COUNTER
6215  1656  J1,       TAD I D /LOAD 2 CHARACTERS
6216  4225            JMS TCP /PRINT 2 CHARACTERS
6217  2256            ISZ D   /D=D+1
6220  2252            ISZ B   /SKIP WHEN LINE PRINTED
6221  5215            JMP J1  /RETURN
6222  2254            ISZ C   /SKIP WHEN ALL LISTED
6223  5212            JMP J2  /RETURN
6224  5655            JMP I MON       /RETURN TO MONITPR
6225  0000  TCP,      0       /SUBROUTINE TO PRINT 2 CHAR.
6226  3243            DCA B1  /STORE 2 CHARACTERS
6227  1243            TAD B1  /LOAD SAME CHARACTERS
6230  0245            AND C1  /MASK LAST 6 BITS
6231  7112            CLL RTR /ROTATE 2 RIGHT
6232  7112            CLL RTR / "
6233  7112            CLL RTR / "
6234  1244            TAD C2  /GENERATE ASII
6235  4647            JMS I TYPE      /TYPE SUBROUTINE
6236  1243            TAD B1  /LOAD CHARACTERS
6237  0246            AND C3  /MASK FIRST 6 BITS
6240  1244            TAD C2  /GENERATE ASII
6241  4647            JMS I TYPE      /TYPE SUBROUTINE
6242  5625            JMP I TCP       /RETURN
6243  0000  B1,       0       /BUFFER
6244  0240  C2,       240     /ASII FOR SPACE
6245  7700  C1,       7700    /MASK FOR LAST 6 BITS
6246  0077  C3,       77      /MASK FOR FIRST 6 BITS
6247  6676  TYPE,     6676
6250  6665  CRLF,     6665
6251  7770  A,        7770    /-8
6252  0000  B,        0       /BUFFER
6253  7773  CC,       7773    /-5
6254  0000  C,        0       /BUFFER
6255  7000  MON,      7000    /MONITOR ADDRESS
```

```
6256  0000  D,      0
6257  6260  F,      .+1      /ADDRESS OF E
6260  5500  E,      5500     /LIST OF PROG. ON TAPE FOLLOWS
6261  0035         0035
6262  0055         0055
6263  5756         5756
6264  5164         5164
6265  5762         5762
6266  0000         0000
6267  0000         0000
6270  2022         2022
6271  0035         0035
6272  0045         0045
6273  4451         4451
6274  6457         6457
6275  6200         6200
6276  0000         0000
6277  0000         0000
6300  2023         2023
6301  0035         0035
6302  0060         0060
6303  4154         4154
6304  0051         0051
6305  5151         5151
6306  0000         0000
6307  0000         0000
6310  2024         2024
6311  0035         0035
6312  0057         0057
6313  4464         4464
6314  0054         0054
6315  5767         5767
6316  0000         0000
6317  0000         0000
6320  2025         2025
6321  0035         0035
6322  0050         0050
6323  4554         4554
6324  6000         6000
6325  4257         4257
6326  5764         5764
6327  6360         6360

                   *6440
6440  7300  STOREM, CLA CLL /CLEAR AC & LINK
6441  1357         TAD M   /LOAD TAPE LABEL
6442  3753         DCA I BUF       /STORE
6443  1360         TAD A   /START ADDRESS
6444  3361         DCA B   /STORE
6445  4762         JMS I  WRBOT
6446  4755         JMS I  WREOF
6447  4747         JMS I  WRTLB
6450  4754         JMS I  WRLOR
```

```
6451  4755          JMS I WREOF
6452  4762          JMS I WRBOT
6453  4755          JMS I WREOF
6454  4763          JMS I WRITE
6455  6754          PSMS    /SLEW MODE SELECT
6456  4764          JMS I READY
6457  7300          CLA CLL /CLEAR AC & LINK
6460  1761          TAD I B /LOAD WORD
6461  6744          PLDS    /WRITE WORD
6462  6741          ISDF    /SKIP ON DATA FLAG
6463  5262          JMP.-1  /JUMP
6464  2361          ISZ B   /INC. & SKIP ADDRESS
6465  5257          JMP.-6  /JUMP
6466  4754          JMS I WREOR
6467  4755          JMS I WREOF
6470  4750          JMS I REWIND
6471  4756          JMS I TYPEX
6472  5741          JMP I MON       /RETURN TO MONITOR
6473  7300  ERASE,  CLA CLL /CLEAR AC & LINK
6474  6046          TLS     /CLEAR PRINT FLAG
6475  4743          JMS I CRLF
6476  7300          CLA CLL
6477  1336          TAD SIGN        /"#"
6500  4742          JMS I TYPE
6501  1337          TAD QUE /"?"
6502  4742          JMS I TYPE
6503  4743          JMS I CRLF
6504  4744          JMS I FORML
6505  4745          JMS I FLABEL
6506  4746          JMS I RDTLB
6507  4750          JMS I REWIND
6510  1751          TAD I LABEL     /LOAD LABEL
6511  7041          CIA     /2'S COMP.
6512  1752          TAD I KEY       /ADD KEY
6513  7710          SPA CLA /SKIP IF AC>=0; CLEAR
6514  5326          JMP ERR /JUMP TO ERROR ROUTINE
6515  1751          TAD I LABEL     /LOAD LABEL
6516  3753          DCA I BUF       /STORE LABEL
6517  4745          JMS I FLABEL
6520  4747          JMS I WRTLB
6521  4754          JMS I WREOR
6522  4755          JMS I WREOF
6523  4750          JMS I REWIND
6524  4756          JMS I TYPEX
6525  5741          JMP I MON       /RETURN TO MONITOR
6526  7300  ERR,    CLA CLL
6527  6046          TLS     /CLEAR PRINT FLAG
6530  4743          JMS I CRLF
6531  7300          CLA CLL
6532  1340          TAD E   /"E"
6533  4742          JMS I TYPE
6534  4743          JMS I CRLF
6535  5741          JMP I MON       /RETURN TO MONITOR
```

```
6536  0243  SIGN,    0243     /"#"
6537  0277  QUE,     0277     /"?"
6540  0305  E,       0305     /"E"
6541  7000  MON,     7000     /ADDRESS OF MONITOR
6542  6676  TYPE,    6676
6543  6665  CRLF,    6665
6544  7063  FORML,   7063
6545  7263  FLABEL,  7263
6546  7277  RDTLB,   7277
6547  7312  WRTLB,   7312
6550  7250  REWIND,  7250
6551  7753  LABEL,   7753
6552  7755  KEY,     7755
6553  7754  BUF,     7754
6554  7230  WREOR,   7230
6555  7240  WREOF,   7240
6556  7052  TYPEX,   7052
6557  0003  M,       0003     /TAPE LABEL
6560  6000  A,       6000     /START ADDRESS
6561  0000  B,       0000     /BUFFER
6562  7217  WRBOT,   7217
6563  7204  WRITE,   7204
6564  7200  READY,   7200


                     *6600
6600  7300  STORE,   CLA CLL /CLEAR AS & LINK
6601  4655           JMS I FLABEL
6602  4656           JMS I RDTLB
6603  4654           JMS I REWIND
6604  7201           CLA IAC /AC=1
6605  1647           TAD I KEY        /BUMP COUNTER
6606  3647           DCA I KEY        /STORE
6607  1647           TAD I KEY        /LOAD
6610  3646           DCA I BUF        /STORE
6611  4655           JMS I FLABEL
6612  4657           JMS I WRTLB
6613  4660           JMS I WREOR
6614  4661           JMS I WREOF
6615  4654           JMS I REWIND
6616  4662           JMS I SEARCH
6617  1244           TAD A   /LOAD START ADDRESS
6620  3245           DCA AD  /STORE
6621  4663           JMS I WRITE
6622  6754           PSMS    /SLEW MODE SELECT
6623  4664           JMS I READY
6624  7300  WW,      CLA CLL
6625  1645           TAD I AD         /LOAD WORD
6626  6744           PLDS    /WRITE WORD
6627  6741           PSDF    /SKIP ON DATA FLAG
6630  5227           JMP.-1  /JUMP
6631  2245           ISZ AD  /INC. ADDRESS
6632  1245           TAD AD  /LOAD ADDRESS
6633  1250           TAD COUNT        /LOAD TOP ADDRESS
```

```
6634  7640            SZA CLA /SKIP AC=0; CLEAR
6635  5224            JMP WW  /JUMP
6636  4660            JMS I WREOR
6637  4661            JMS I WREOF
6640  4654            JMS I REWIND
6641  4652            JMS I TYPEX
6642  4653            JMS I NUMBER
6643  5651            JMP I MON       /RETURN TO MONITOR
6644  0000  A,        0000    /START ADDRESS
6645  0000  AD,       0000    /BUFFER
6646  7754  BUF,      7754    /ADDRESS OF BUF
6647  7755  KEY,      7755    /ADDRESS OF KEY
6650  1200  COUNT,    1200    /TOP ADDRESS
6651  7000  MON,      7000    /ADDRESS OF MONITOR
6652  7052  TYPEX,    7052    /TYPE"X"
6653  7103  NUMBER,   7103
6654  7250  REWIND,   7250
6655  7263  FLABEL,   7263
6656  7277  RDTLB,    7277
6657  7312  WRTLB,    7312
6660  7230  WREOR,    7230
6661  7240  WREOF,    7240
6662  7324  SEARCH,   7324
6663  7204  WRITE,    7204
6664  7200  READY,    7200
6665  0000  CRLF,     0       /CARRIAGE RETURN LINE FEED
6666  7300            CLA CLL /CLEAR AC & LINK
6667  1274            TAD C3  /LOAD C.R.
6670  4276            JMS TYPE        /TYPE
6671  1275            TAD C4  /LOAD L.F.
6672  4276            JMS TYPE        /TYPE
6673  5665            JMP I CRLF      /RETURN
6674  0215  C3,       0215    /CARRIAGE RETURN
6675  0212  C4,       0212    /LINE FEED
6676  0000  TYPE,     0       /TYPE SUBROUTINE
6677  6041            TSF     /SKIP IF FLAG SET
6700  5277            JMP.-1  /JUMP
6701  6046            TLS     /PRINT
6702  7300            CLA CLL /CLEAR AC & LINK
6703  5676            JMP I TYPE      /RETURN
6704  0000  LISN,     0       /ACCEPT CHARACTER SUBROUTINE
6705  6031            KSF
6706  5305            JMP.-1
6707  6036            KRB
6710  6046            TLS
6711  5704            JMP I LISN      /RETURN
6712  0000  CLEAR,    0       /CLEAR SYS.
6713  7300            CLA CLL /CLEAR AC & LINK
6714  6714            PFRD    /FWD. SEL. READ
6715  6736            PCHLT   /CLEAR TAPE
6716  6714            PFRD
6717  6736            PCHLT
6720  6701            PSSR    /SKIP IF SYS. READY
```

```
6721  5320          JMP.-1  /JUMP
6722  7300          CLA CLL
6723  5712          JMP I CLEAR     /RETURN

                    *7000
7000  4777  MON,     JMS I CLEAR     /CLEAR SYS.
7001  6046  A,      TLS     /CLEAR PRINT FLAG
7002  4764          JMS I CRLF      /CRLF
7003  1341  B,      TAD C1  /LOAD "?"
7004  4765          JMS I TYPE      /TYPE
7005  4764          JMS I CRLF      /CRLF
7006  4766          JMS I LISN      /LISN
7007  3336          DCA B1  /STORE CHARACTER
7010  4764          JMS I CRLF      /CRLF
7011  1336          TAD B1
7012  1342          TAD C2
7013  7650          SNA CLA /SKIP IF NOT "L"
7014  5767          JMP I LOAD      /LOAD ROUTINE
7015  1336          TAD B1
7016  1343          TAD C3
7017  7650          SNA CLA /SKIP IF NOT "S"
7020  5770          JMP I STORE     /STORE ROUTINE
7021  1336          TAD B1
7022  1344          TAD C4
7023  7650          SNA CLA /SKIP IF NOT "M"
7024  5771          JMP I LMON      /LOAD MONITOR ROUTINE
7025  1336          TAD B1
7026  1345          TAD C5
7027  7650          SNA CLA /SKIP IF NOT "T"
7030  5772          JMP I LIST      /LIST PROG. ON TAPE
7031  1336          TAD B1
7032  1346          TAD C6
7033  7650          SNA CLA /SKIP IF NOT "C"
7034  5773          JMP I CODE      /LIST CODE ROUTINE
7035  1336          TAD B1
7036  1347          TAD C7
7037  7650          SNA CLA /SKIP IF NOT "P"
7040  5774          JMP I PAD       /SCRATCH PAD ROUTINE
7041  1336          TAD B1
7042  1350          TAD C8
7043  7650          SNA CLA /SKIP IF NOT "R"
7044  5775          JMP I ERASE     /ERASE ROUTINE
7045  1336          TAD B1
7046  1351          TAD C9
7047  7650          SNA CLA /SKIP IF NOT "N"
7050  5776          JMP I STOREM    /STORE MONITOR ROUTINE
7051  5203          JMP B   /ASK FOR COMMAND
7052  0000  TYPEX,  0       /TYPE EXECUTED ROUTINE
7053  7300          CLA CLL /CLEAR AC & LINK
7054  6046          TLS     /CLEAR PRINT FLAG
7055  4764          JMS I CRLF      /CRLF
7056  7300          CLA CLL
7057  1352          TAD C10 /LOAD "X"
7060  4765          JMS I TYPE
```

```
7061  4764          JMS I CRLF
7062  5652          JMP I TYPEX      /RETURN
7063  0000  FORML, 0        /FORM LABEL ROUTINE
7064  4766          JMS I LISN
7065  1356          TAD M260         /STRIP
7066  3336          DCA B1   /STORE
7067  4766          JMS I LISN
7070  1356          TAD M260         /STRIP
7071  3337          DCA B2   /STORE
7072  4764          JMS I CRLF
7073  1336          TAD B1   /LOAD
7074  7104          CLL RAL /SHIFT LEFT 1
7075  7104          CLL RAL
7076  7104          CLL RAL
7077  1337          TAD B2   /FORM CHAR.
7100  1354          TAD K    /ADD 2
7101  3763          DCA I LABEL      /STORE
7102  5663          JMP I FORML      /RETURN
7103  0000  NUMBER, 0        /TYPE PROG. #
7104  6046          TLS      /CLEAR PRINT FLAG
7105  4764          JMS I CRLF
7106  1762          TAD I KEY        /LOAD COUNT
7107  1355          TAD MK   /ADD -2
7110  3336          DCA B1   /STORE
7111  1336          TAD B1   /LOAD
7112  0360          AND MASK1        /STRIP
7113  7110          CLL RAR /SHIFT RIGHT 1
7114  7110          CLL RAR
7115  7110          CLL RAR
7116  1357          TAD K260         /FORM ASCII
7117  3337          DCA B2   /STORE
7120  1336          TAD B1   /LOAD
7121  0361          AND MASK2        /STRIP
7122  1357          TAD K260         /FORM ASCII
7123  3340          DCA B3   /STORE
7124  6046          TLS
7125  1353          TAD C11 /"#"
7126  4765          JMS I TYPE       /TYPE
7127  7300          CLA CLL
7130  1337          TAD B2   /LOAD 1ST #
7131  4765          JMS I TYPE
7132  7300          CLA CLL
7133  1340          TAD B3   /LOAD 2ND #
7134  4765          JMS I TYPE
7135  5703          JMP I NUMBER     /RETURN
7136  0000  B1,     0000     /BUFFER
7137  0000  B2,     0000
7140  0000  B3,     0000
7141  0277  C1,     0277     /"?"
7142  7464  C2,     7464     /MOD "L"
7143  7455  C3,     7455     /MOD "S"
7144  7463  C4,     7463     /MOD "M"
7145  7454  C5,     7454     /MOD "T"
```

```
7146  7475  C6,       7475     /MOD "C"
7147  7460  C7,       7460     /MOD "P"
7150  7456  C8,       7456     /MOD "R"
7151  7462  C9,       7462     /MOD "N"
7152  0330  C10,      0330     /"X"
7153  0243  C11,      0243     /"#"
7154  0002  K,        0002     /+2
7155  7776  MK,       7776     /-2
7156  7520  M260,     7520     /-260
7157  0260  K260,     0260     /+260
7160  0070  MASK1,    0070     /10'S MASK
7161  0007  MASK2,    0007     /1'S MASK
7162  7755  KEY,      7755     /KEY
7163  7753  LABEL,    7753     /LABEL
7164  6665  CP' F,    6665
7165  6676  TY:E,     6676
7166  6704  LIS'N,    6704
7167  7467  LOAD,     7467
7170  6600  STORE,    6600
7171  7400  LMON,     7400     /LOAD MONITOR
7172  6204  LIST,     6204     /LIST PROG. ON TAPE
7173  6000  CODE,     6000     /CODE FOR MONITOR
7174  7350  PAD,      7350
7175  6473  ERASE,    6473
7176  6440  STOREM,   6440     /STORE MONITOR
7177  6712  CLEAR,    6712


                      *7200
7200  0000  READY,    0        /READY SUBROUTINE
7201  6701            PSSR     /SKIP IF SYSTEM READY
7202  5201            JMP.-1   /JUMP
7203  5600            JMP I READY      /RETURN
7204  0000  WRITE,    0        /SET UP FOR WRITE SUBROUTINE
7205  7300            CLA CLL /CLEAR AC & LINK
7206  6702            PWMS     /WRITE MODE SELECT
7207  4200            JMS READY        /READY
7210  5604            JMP I WRITE      /RETURN
7211  0000  READ,     0        /SET UP FOR READ SUBROUTINE
7212  6736            PCHLT    /CLEAR FLAGS
7213  4200            JMS READY        /READY
7214  6714            PFRD     /FWD. SELECT READ
7215  4200            JMS READY        /READY
7216  5611            JMP I READ       /RETURN
7217  0000  WRBOT,    0        /WRITE BOT SUBROUTINE
7220  7300            CLA CLL /CLEAR AC & LINK
7221  4204            JMS WRITE        /WRITE
7222  6704            PBOT     /WRITE BOT
7223  6741            PSDF     /SKIP ON DATA FLAG
7224  5223            JMP.-1   /JUMP
7225  6736            PCHLT    /CLEAR FLAGS
7226  4200            JMS READY
7227  5617            JMP I WRBOT      /RETURN
7230  0000  WREOR,    0        /WRITE EOR SUBROUTINE
```

```
7231  7300            CLA CLL /CLEAR AC & LINK
7232  4204            JMS WRITE       /WRITE
7233  6771            PEOR    /WRITE EOR
7234  6741            PSDF    /SKIP ON DATA FLAG
7235  5234            JMP.-1  /JUMP
7236  4200            JMS READY
7237  5630            JMP I WREOR     /RETURN
7240  0000  WREOF,    0       /WRITE EOF SUBROUTINE
7241  7300            CLA CLL /CLEAR AC & LINK
7242  4204            JMS WRITE       /WRITE
7243  6722            PEOF    /WRITE EOF
7244  6741            PSDF    /SKIP ON DATA FLAG
7245  5244            JMP.-1  /JUMP
7246  4200            JMS READY       /READY
7247  5640            JMP I WREOF     /RETURN
7250  0000  REWIND,   0       /REWIND SUBROUTINE
7251  4211            JMS READ        /READ
7252  6764            PREW    /REWIND & LOAD
7253  6761            PSSS    /SENSE SYS. STATUS
7254  0262            AND BOT /BOT MASK
7255  7650            SNA CLA /SKIP AC NOT = 0; CLEAR
7256  5253            JMP.-3  /JUMP
7257  6736            PCHLT   /CLEAR FLAGS
7260  4200            JMS READY       /READY
7261  5650            JMP I REWIND    /RETURN
7262  0100  BOT,      0100    /BOT,LOAD POINT MASK
7263  0000  FLABEL,   0       /FIND TAPE LABEL SUBROUTINE
7264  4211            JMS READ        /READ ROUTINE
7265  6754            PSMS    /SLEW MODE SEL.
7266  4200            JMS READY
7267  7300            CLA CLL
7270  6761            PSSS    /SENSE SYS. STATUS
7271  0347            AND EOF /EOF MASK
7272  7650            SNA CLA /SKIP AC NOT = 0; CLEAR
7273  5270            JMP.-3
7274  6736            PCHLT
7275  4200            JMS READY
7276  5663            JMP I FLABEL    /RETURN
7277  0000  RDTLB,    0       /READ TAPE LABEL SUBROUTINE
7300  4211            JMS READ        /READ ROUTINE
7301  6754            PSMS    /SLEW MODE SELECT
7302  7300            CLA CLL /CLEAR AC & LINK
7303  6751            PRDS    /READ LABEL
7304  6741            PSDF    /SKIP ON DATA FLAG
7305  5304            JMP.-1  /JUMP
7306  3746            DCA I KEY       /STORE LABEL
7307  6736            PCHLT   /CLEAR FLAGS
7310  4200            JMS READY       /READY
7311  5677            JMP I RDTLB     /RETURN
7312  0000  WRTLB,    0       /WRITE TAPE LABEL SUBROUTINE
7313  4204            JMS WRITE       /WRITE ROUTINE
7314  6754            PSMS    /SLEW MODE SELECT
7315  1745            TAD I BUF       /LOAD NEW LABEL
```

```
7316  6744           PLDS    /LOAD DATA BUFFER & STEP
7317  6741           PSDF    /SKIP ON DATA FLAG
7320  5317           JMP.-1  /JUMP
7321  6736           PCHLT   /CLEAR FLAG
7322  4200           JMS READY       /READY
7323  5712           JMP I WRTLB     /RETURN
7324  0000  SEARCH,  0       /SEARCH SUBROUTINE
7325  1746           TAD I KEY       /LOAD KEY COUNTER
7326  7041           CIA     /2'S COMP.
7327  3746           DCA I KEY       /STORE COUNTER
7330  4211           JMS READ        /READ
7331  6772           PHAS    /HI SPEED SELECT
7332  4200           JMS READY       /READY
7333  7300  GAP,     CLA CLL /CLEAR AC & LINK
7334  6761           PSSS    /SENSE SYS. STATUS
7335  0347           AND EOF /AND EOF MASK
7336  7650           SNA CLA /SKIP AC NOT =0; CLEAR
7337  5334           JMP.-3  /JUMP
7340  2746           ISZ I KEY       /BUMP COUNTER
7341  5333           JMP GAP /JUMP
7342  6736           PCHLT   /CLEAR FLAG
7343  4200           JMS READY       /READY
7344  5724           JMP I SEARCH    /RETURN
7345  7754  BUF,     7754    /LABEL
7346  7755  KEY,     7755    /ADDRESS
7347  0010  EOF,     0010    /SET BIT 8 TO 1
7350  7300  PAD,     CLA CLL /CLEAR AC & LINK
7351  1367           TAD T   /LOAD COUNT
7352  3372           DCA TT  /STORE
7353  4263           JMS FLABEL      /FIND LABEL
7354  4271           JMS RDTLB       /READ TAPE LABEL
7355  4250           JMS REWIND      /REWIND
7356  7201           CLA IAC /AC=1
7357  1746           TAD I KEY       /LOAD KEY
7360  3746           DCA I KEY       /STORE
7361  4324           JMS SEARCH      /SEARCH
7362  4217           JMS WRBOT       /WRITE BOT
7363  2372           ISZ TT  /INC. & SKIP
7364  5362           JMP.-2  /JUMP
7365  4240           JMS WREOF       /EOF
7366  5771           JMP I MON       /RETURN TO MONITOR
7367  7742  T,       7742    /-36
7370  7777  L,       7777    /-1
7371  7000  MON,     7000    /MONITOR
7372  0000  TT,      0000    /BUFFER

                     *7400
7400  7300  LMON,    CLA CLL /CLEAR AC & LINK
7401  1223           TAD S   /LOAD START ADDRESS
7402  3222           DCA SS  /STORE
7403  1216           TAD P   /LOAD NEW ADDRESS
7404  3217           DCA PP  /STORE
7405  1220           TAD C   /LOAD WORD COUNT
```

```
7406  3221          DCA CC  /STORE
7407  1622          TAD I SS        /LOAD WORD
7410  3617          DCA I PP        /STORE
7411  2222          ISZ SS  /INC. ADDRESS
7412  2217          ISZ PP  / "     "
7413  2221          ISZ CC  /BUMP COUNTER
7414  5207          JMP.-5  /JUMP
7415  5616          JMP I P /CONTROL TO LMON
7416  0100  P,       0100    /NEW ADDRESS
7417  0000  PP,      0000    /BUFFER
7420  7735  C,       7735    /COUNTER
7421  0000  CC,      0000    /BUFFER
7422  0000  SS,      0000    /BUFFER
7423  7424  S,       .+1     /ADDRESS OF NN
7424  7300  NN,      7300    /START CODE HERE
7425  1130          1130
7426  3531          3531
7427  4536          4536
7430  1132          1132
7431  3133          3133
7432  4537          4537
7433  6754          6754
7434  4542          4542
7435  7300          7300
7436  6751          6751
7437  6741          6741
7440  5113          5113
7441  3533          3533
7442  2133          2133
7443  5111          5111
7444  7300          7300
7445  6761          6761
7446  0134          0134
7447  7640          7640
7450  7402          7402
7451  4535          4535
7452  4540          4540
7453  5541          5541
7454  0003          0003
7455  7755          7755
7456  6000          6000
7457  0000          0000
7460  7610          7610
7461  7250          7250
7462  7324          7324
7463  7211          7211
7464  7052          7052
7465  7000          7000
7466  7200          7200
7467  7300  LOAD,    CLA CLL /CLEAR AC & LINK
7470  6046          TLS     /CLEAR PRINT FLAG
7471  4774          JMS I CRLF      /CRLF
7472  7300          CLA CLL /CLEAR AC & LINK
```

```
7473  1360          TAD SIGN          /"#"
7474  4775          JMS I TYPE        /TYPE
7475  1361          TAD QUE /"?"
7476  4775          JMS I TYPE        /TYPE
7477  4774          JMS I CRLF        /CRLF
7500  4772          JMS I FORML       /FORM LABEL
7501  4766          JMS I FLABEL      /FIND LABEL
7502  4767          JMS I RDTLB       /READ TAPE LABEL
7503  4765          JMS I REWIND      /REWIND
7504  1764          TAD I LABEL       /LOAD LABEL
7505  7041          CIA      /2'S COMP.
7506  1763          TAD I KEY         /LOAD TAPE LABEL
7507  7710          SPA CLA /SKIP IF AC>=0; CLEAR
7510  5344          JMP ERROR         /ERROR ROUTINE
7511  1764          TAD I LABEL       /LOAD CORRECT LABEL
7512  3763          DCA I KEY         /STORE
7513  4770          JMS I SEARCH      /SEARCH
7514  1354          TAD A    /LOAD START ADDRESS
7515  3355          DCA AD   /STORE
7516  4771          JMS I READ        /READ
7517  6754          PSMS     /SLEW MODE SELECT
7520  4777          JMS I READY
7521  7300          CLA CLL /CLEAR AC & LINK
7522  6751  RR,     PRDS     /READ
7523  6741          PSDF     /SKIP ON DATA FLAG
7524  5323          JMP.-1   /JUMP
7525  3755          DCA I AD          /STORE WORD
7526  2355          ISZ AD   /INC. ADDRESS
7527  1355          TAD AD   /LOAD ADDRESS
7530  1356          TAD COUNT         /LOAD TOP ADDRESS
7531  7640          SZA CLA /SKIP AC=0; CLEAR
7532  5322          JMP RR   /JUMP
7533  7300          CLA CLL /CLEAR AC & LINK
7534  6761          PSSS     /SENSE SYS. STATUS
7535  0357          AND MSK /ERROR MASK
7536  7640          SZA CLA /SKIP AC=0; CLEAR
7537  5343          JMP ERR /JUMP
7540  4765          JMS I REWIND      /REWIND
7541  4773          JMS I TYPEX       /TYPE "X"
7542  5776          JMP I MON         /RETURN TO MONITOR
7543  4765  ERR,    JMS I REWIND
7544  7300  ERROR,  CLA CLL
7545  6046          TLS      /CLEAR PRINT FLAG
7546  4774          JMS I CRLF        /CRLF
7547  7300          CLA CLL /CLEAR AC & LINK
7550  1362          TAD E    /LOAD "E"
7551  4775          JMS I TYPE        /TYPE
7552  4774          JMS I CRLF        /CRLF
7553  5776          JMP I MON         /RETURN TO MONITOR
7554  0000  A,      0000     /START ADDRESS
7555  0000  AD,     0000     /BUFFER
7556  1200  COUNT,  1200     /COUNTER
7557  7610  MSK,    7610     /ERROR MASK
```

```
7560  0243  SIGN,    0243     /"#"
7561  0277  QUE,     0277     /"?"
7562  0305  E,       0305     /"E"
7563  7755  KEY,     7755     /ADDRESS OF KEY
7564  7753  LABEL,   7753     /ADDRESS OF LABEL
7565  7250  REWIND,  7250
7566  7263  FLABEL,  7263
7567  7277  RDTLB,   7277
7570  7324  SEARCH,  7324
7571  7211  READ,    7211
7572  7063  FORML,   7063
7573  7052  TYPEX,   7052
7574  6665  CRLF,    6665
7575  6676  TYPE,    6676
7576  7000  MON,     7000     /MONITOR
7577  7200  READY,   7200


                     *7600
 7600  7300  RECOV,  CLA CLL /CLEAR AC & LINK
 7601  6714          PFRD     /FWD. SEL. READ
 7602  6701          PSSR     /SKIP IF SYS. READY
 7603  5202          JMP.-1   /JUMP
 7604  6732  S,      PCLR     /CLEAR STATUS REG.
 7605  6754          PSMS     /SLEW MODE SEL.
 7606  7300          CLA CLL
 7607  6761          PSSS     /SENSE SYS. STATUS
 7610  0367          AND EOF  /EOF MASK
 7611  7650          SNA CLA  /SKIP AC NOT = 0; CLEAR
 7612  5207          JMP.-3   /JUMP
 7613  2370          ISZ C    /INC. & COUNT
 7614  5204          JMP S    /AGAIN
 7615  5356          JMP CONT         /CONTINUE
 7616  0000          0000
 7617  0000          0000
 7620  0000          0000
 7621  0000          0000
 7622  0000          0000
 7623  0000          0000
 7624  0000          0000
 7625  7402  BIN,     7402
 7626  0000          0000
 7627  3212          3212
 7630  4260          4260
 7631  1300          1300
 7632  7750          7750
 7633  5237          5237
 7634  2212          2212
 7635  7040          7040
 7636  5227          5227
 7637  1212          1212
 7640  7640          7640
 7641  5230          5230
 7642  1214          1214
```

7643	0274	0274
7644	1341	1341
7645	7510	7510
7646	2226	2226
7647	7750	7750
7650	5626	5626
7651	1214	1214
7652	0256	0256
7653	1257	1257
7654	3213	3213
7655	5230	5230
7656	0070	0070
7657	6201	6201
7660	7631	7631
7661	5262	5262
7662	6031	6031
7663	5262	5262
7664	6036	6036
7665	3214	3214
7666	1214	1214
7667	5660	5660
7670	6011	6011
7671	5270	5270
7672	6016	6016
7673	5265	5265
7674	0300	0300
7675	4343	4343
7676	7041	7041
7677	1215	1215
7700	7402	7402
7701	6032	6032
7702	6014	6014
7703	6214	6214
7704	1257	1257
7705	3213	3213
7706	7604	7604
7707	7700	7700
7710	1353	1353
7711	1352	1352
7712	3261	3261
7713	4226	4226
7714	5313	5313
7715	3215	3215
7716	1213	1213
7717	3336	3336
7720	1214	1214
7721	3376	3376
7722	4260	4260
7723	3355	3355
7724	4226	4226
7725	5275	5275
7726	4343	4343
7727	7420	7420

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7730  5336            5336
7731  3216            3216
7732  1376            1376
7733  1355            1355
7734  1215            1215
7735  5315            5315
7736  6201            6201
7737  3616            3616
7740  2216            2216
7741  7600            7600
7742  5332            5332
7743  7676            7676
7744  1376            1376
7745  7106            7106
7746  7006            7006
7747  7006            7006
7750  1355            1355
7751  5743            5743
7752  5262            5262
7753  0000  LABEL,    0000
7754  0000  BUF,      0000
7755  0003  KEY,      0003
7756  7300  CONT,     CLA CLL /CLEAR AC & LINK
7757  6751            PRDS    /READ
7760  6741            PSDF    /SKIP ON DATA FLAG
7761  5360            JMP.-1  /JUMP
7762  3771            DCA I AD        /STORE WORD
7763  2371            ISZ AD  /INC. ADDRESS
7764  2372            ISZ WCNT        /INC. & SKIP WORD CNT.
7765  5356            JMP.-7  /JUMP
7766  7402            HLT     /HALT
7767  0010  EOF,      0010    /EOF MASK
7770  7775  C,        7775    /-3
7771  6000  AD,       6000    /START ADDRESS
7772  1600  WCNT,     1600    /WORD COUNT
7773  0000            0000
7774  0000            0000
7775  0000            0000
7776  0000            0000
7777  5301            5301
```

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Unclassified
Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

Naval Postgraduate School
Monterey, California 93940

2a. REPORT SECURITY CLASSIFICATION

Unclassified

2b. GROUP

3. REPORT TITLE

A Monitor for the PDP-8/S Computer System

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Master's Thesis; June 1970

5. AUTHOR(S) *(First name, middle initial, last name)*

Glenn Tracy Martinsen

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1970	54	5

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT

The design and implementation of the PDP-8/S Monitor is described. The monitor is an interactive tape driving routine combined with a small operating system. The monitor was implemented in PAL III, the PDP-8 assembly language, for operation in conjunction with a teletype and PI-1250-1 Data Handling System.

DD FORM 1 NOV 68 1473 (PAGE 1)
S/N 0101-807-6811

Unclassified
Security Classification

A-31406

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Monitor						
Tape Driver						
Magnetic Tape System						
Small Computer Operating System						

Thesis
M35928
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A monitor for the PDP-8/S computer system.